A Gravity Survey of the Island of Oahu, Hawaii[1]

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Prior to the present study four pendulum bases had been established on the island by the U. S. Coast and Geodetic Survey (Duerksen, 1943): (1) a submarine pendulum observation at the port of Honolulu by Vening Meinesz (1934), (2) submarine pendulum observations at various sites at Pearl Harbor by personnel of the Lamont Geological Survey (Worzel, in press), (3) pendulum observations at the Bishop Museum (Woollard and Rose, 1963), and (4) a reconnaissance gravimeter survey at some 30 regionally distributed sites by Woollard (1951). Although personnel of the U. S. Geological Survey and the U. S. Air Force Air Photographic and Charting Survey had also established gravimeter stations in some areas, their data were not generally available.

The present survey was a follow-up on the original work of Woollard (1951), who had shown that the gravity field was characterized by positive Bouguer anomalies ranging from +197 to +309 mgal, and that the maximum anomalies were correlated with two major volcanic calderas over which there appeared to be a local effect of about +110 mgal. Although Vening Meinesz (1941) had concluded that the Hawaiian Islands represented an extra mass on the earth's crust having a density of about 2.94 g/cc, Woollard's analysis of the gravity data suggested a mean density of only 2.3 g/cc and that only the volcanic pipes creating the local anomalies were characterized by a high density.

Inasmuch as in the interim since Woollard's original reconnaissance survey a considerable amount of crustal seismic information had been obtained as well as offshore gravity data, it was decided to make a more complete gravity survey of Oahu which could be analyzed using modern computer techniques. Oahu also constituted the logical place for a meaningful integrated geophysical study of the subsurface mass distribution associated with volcanic calderas in that, through erosion and crustal subsidence, both of the calderas having gravity expression lay essentially at sea level. Thus, there was no significant surficial mass contribution to the anomalies. Other favorable factors associated with Oahu were the road system giving easy access to most of the island, generally good elevation control, the ability to carry out gravity surveys over the center of volcanic pipes without the complications of major elevation changes, and local U. S. Marine Corps helicopter support for making observations in otherwise inaccessible areas. In all, some 512 gravity stations were established; their locations are indicated in Figure 1. The table of principal facts is reported elsewhere (Hawaii Inst. Geoph., 1965, Table 6). The observations were established by the writers with the assistance of A. S. Furumoto and L. W. Kroenke.

BASE STATIONS

The base value used was that for Hickam Air Force Base, which had been established originally by Woollard in 1948 and subsequently reoccupied and tied to the Washington national gravity base many times (Woollard, 1950; and Woollard and Rose, 1963). The adopted value for this base on the Potsdam (Bad Harzburg) system is 978.9337 gal. Because Honolulu is used extensively as a control point for all gravity surveys in the Pacific area, and the International Air Terminal is too far removed from Hickam Air Force Base to permit reoccupation of the Hickam base, Woollard had established a number of auxiliary bases (Woollard and Rose, 1963). However, because of new construction most of these base sites can no longer be recovered. The descriptions and values of these earlier bases and of new bases established by the writers are given in the following list. Figure 2 shows the base interconnections.

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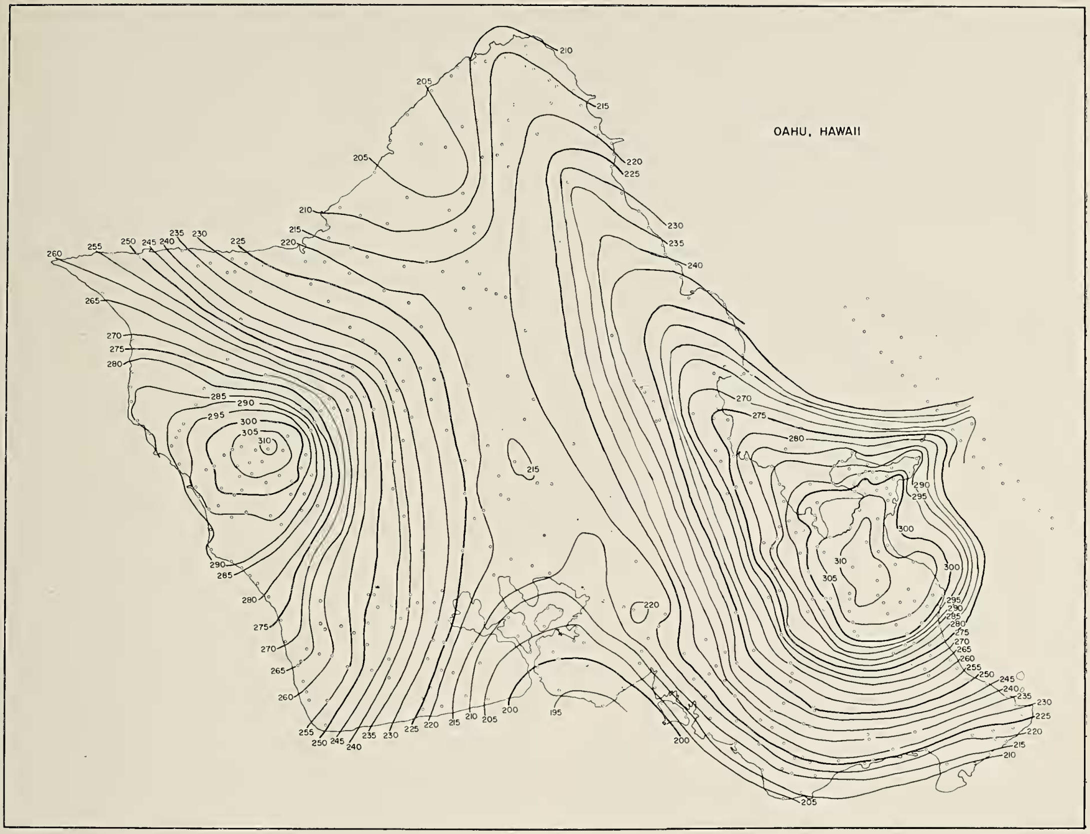

FIG. 1. Bouguer gravity anomaly map of the island of Oahu, Hawaii.

Earlier Gravity Bases

Barbers Point Naval Air Station (WA 442). To left of door to Fleet Logistics Air Terminal, Entrance 2.
21°18.9′N
158°04.5′W 21 ft 978.9720 gal

Hickam Air Force Base (WA 443). In lobby of MATS terminal, next to wall map of Pacific Ocean.
21°20.5′N
157°57.5′W 21 ft 978.9337 gal

Old Honolulu International Airport (WA 444). At base of flag pole by Gate 4A, near Medical Inspection Building.
21°19.5′N
157°55.6′W 13 ft 978.9325 gal

John Rodgers Naval Air Station (WA 445). To left of door to Fleet Logistics Air Terminal.
21°19.2′N
157°55.2′W 6 ft 978.9290 gal

Wheeler Air Force Base (WA 446). At runway 150 ft in front of Hangar 2.
21°29.4′N
158°02.2′W 824 ft 978.9247 gal

Pendulum Station, Bishop Museum. On ground floor of the Administrative and Research Annex Building, in the north corner of Room 2 at floor level, which is about 3 ft below level of ground immediately outside; 40 ft southeast of northwest wall and 3 ft southwest of northeast wall of building.
21°20.2′N
157°52.4′W 80 ft 978.9520 gal

New Gravity Bases

New International Airport Terminal. On ground level sidewalk on street side of terminal, alongside right-hand pillar nearest curb when facing up-ramp nearest incoming domestic baggage center (Waikiki end of terminal).
21°20.1′N
157°55.4′W 11 ft 978.9330 gal

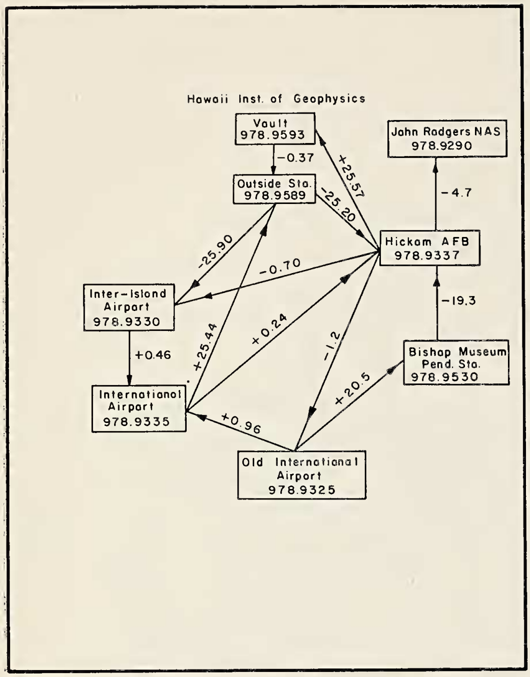

FIG. 2. Local gravity base interconnections, Honolulu, Hawaii.

New Inter-Island Terminal. On concrete sidewalk next to third rock column from Aloha Airlines or fourth rock column from Hawaiian Airlines.

21°20.2′N		
157°55.5′W	11 ft	978.9330 gal

Hawaii Institute of Geophysics (University of Hawaii campus). Primary site: in center of flush (floor) pier in basement vault at southwest end of Institute of Geophysics building.

17°30.6′N		
157°49.2′W	61 ft	978.9593 gal

Secondary site: on concrete walkway about 1 ft left of doorway leading into Room 108 (when facing door), and about 2 ft to the right of a large stone pillar.

17°30.6′N		
157°49.2′W	72 ft	978.9589 gal

DETAILS OF SURVEY

The gravity station observations on Oahu were taken with Worden gravimeter No. 607 and Worden gravimeter No. 366. Most of the stations were taken along public streets and roads, using automobile transportation. Most of the mountain stations were taken at helicopter pads, using helicopter support provided by the Kaneohe Marine Corps Air Station. Certain mountain stations, however, were taken during an overnight foot traverse into the Koolau Range. Except for the foot traverse, readings for drift control were taken at the base station at the beginning and end of each day's work. If possible, reoccupations were made at intermediate times to improve drift control. For the foot traverse the base station tie was made 36 hours after the initial reading. However, overnight drifts were removed by reoccupations and the base tie was used only to remove running drift. Daily drift was normally less than 0.5 mgal per day and, judging from readings taken on the days when intermediate reoccupations were made, assumption of linear drift over an entire day's work seldom produced errors in excess of 0.1 mgal. Elevations were taken from U. S. Geological Survey 7½′ quadrangle maps, by reference to sea level along the coast, or, in those cases where bench marks existed, at U. S. Coast and Geodetic Survey bench marks. The accuracy of the elevations is variable. Elevations for stations taken at bench marks or at points where useful elevations were given on the maps are probably accurate to within 1–2 ft. Most of the other elevations for stations lying along public streets and roads are accurate to 10 ft or better. For a few stations greater elevation errors are possible. Elevation errors of up to 20 ft are possible for those stations established by helicopter in areas of the Koolau and Waianae ranges, and elevations for stations established on the overnight foot traverse could be in error by as much as 50 ft. All latitudes and longitudes were taken from the 7½′ quadrangle maps and are generally accurate to within 0.1′ or better.

REDUCTION OF DATA

Normal data-reduction procedures were carried out for the data, with corrections made for drift and earth tides. The meter constant for meter No. 607 was 0.11457 mgal per scale unit and that for meter No. 366 was 0.050637 mgal per scale unit. Comparisons of these meters against the pendulum stations of the western North American calibration line and intermediate stations established with other gravity meters and comparisons against other meters on the mid-Pacific calibration line indicate that gravimeter No. 607 has a screw effect which causes the calibration constant to vary from 0.1140 to 0.1150 mgal per meter unit for different ranges of the gravimeter. The exact nature of this screw effect has not been definitely established, but since the error to be expected from this source would generally be 0.2 mgal or less no attempt was made to take it into account in the reductions. The screw effect in gravimeter No. 366 was small and did not exceed 0.1 mgal.

Terrain corrections were carried out where it was believed that the effect would be larger than 1–2 mgal. Two different methods were used—the normal circular template method and a profile angle method. The profile angle method is only approximate and the complete Bouguer anomalies obtained by this method may be in error by 1–2 mgal. The simple Bouguer anomalies for most of the stations are probably accurate to better than 1 mgal. A few of the stations where elevation control is uncertain may be in error by as much as 5 mgal.

No detailed interpretation of results will be given here, but a few brief comments can be made. The Bouguer gravity anomaly on the island of Oahu varies from a low of about +190 mgal to a high of about +310 mgal. The lowest value occurs in the Pearl Harbor area and perhaps is caused partly by the thick section of sediments present. The highest values are associated with the Koolau and Waianae volcanic calderas as defined geologically. Positive anomalies of 115 mgal magnitude are associated with each of these calderas. The major northwest rift zone of the Koolau volcano and the south and northwest rift zones of the Waianae volcano have lower gravity positive anomalies associated with them and average +50 mgal above the general level. As seen from the Bouguer anomaly map (Fig. 1), the topographic effect of the island is not pronounced because the gravity effect of the two major volcanic pipes and their associated rifts dominate the gravity field. Also, it is to be noted that although Salt Lake Crater, where inclusions of eclogite are common, has a small gravity effect of about 5 mgal, other late-stage volcanic centers, such as Diamond Head, Koko Head, and Punch Bowl, have no discernible gravity effect. This implies no density-significant contrast between the pipe filling and the surrounding lavas.

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